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 Title: PERFORMANCE MARKERS TO MEASURE BENCHMARK TIMING OF FEATURES IN A PROGRAM

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- ☒ Utility Patent Application: Spec. 27 pgs; 27 claims; Abstract 1 pg.
The fee has been calculated as shown below in the 'Claims as Filed' table.
- ☒ 8 sheets of formal drawings
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CLAIMS AS FILED

Number of Claims Filed	In Excess of:	Number Extra	Rate	Fee
Basic Filing Fee				\$690.00
Total Claims				
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Independent Claims				
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Performance Markers to Measure Benchmark Timing of Features in a Program

Related Applications

5 The instant application is related to two concurrently assigned and concurrently filed
U.S. Patent Applications, PERFORMANCE MARKERS TO MEASURE PERFORMANCE OF
FEATURES IN A PROGRAM, Serial No. _____, filed _____, (Attorney
Docket M&G 40062.69-US-01) AND PERFORMANCE MARKERS TO MEASURE BENCHMARK
TIMING OF A PLURALITY OF FEATURES IN AN APPLICATION PROGRAM, Serial No. _____,
10 filed _____, (Attorney Docket No. 40062.69-US-03).

Technical Field

 This application relates in general to a method, apparatus, and article of manufacture
for providing performance markers for testing of applications, and more particularly to a
method, apparatus, and article of manufacture for inserting performance markers into
15 programs to obtain and provide benchmark timing data regarding the run-time operation of
the programs.

Background of the Invention

 One problem facing application program developers is how their application
20 programs are to be tested. In order for the developers to test these programs, the developers
need access to runtime state information regarding the internal operation of the program.
This data can include memory usage, memory location contents, timing measurements for the

execution of portions of the program, and similar data related to the state of the program while executing.

In the past, application developers have needed to use third party tools to re-instrument the target application (an example of this being post linker tools like Profilers which modify the application for the purpose of adding measurement code) with instructions that maintain and store the needed state data in locations that provide access by the developers. In doing this, the application developers are changing the application program being developed by artificially inserting this additional code. This insertion of code implies that the application developers are actually testing a program that is different from the application program, which is ultimately delivered to end users. These differences caused by the insertion of this test code may or may not affect the ability of a programmer to adequately test the application program in an environment as close to the end user's working environment as possible. Additionally, the location of these insertion points is quite often limited to function call boundaries increasing the granularity at which the timings can be taken. This limits the precision of the measurements.

This situation is especially acute to benchmark testing in which the developer wishes to measure the time the application program requires to perform a certain code block of functionality. In benchmarking, the insertion of extra instructions related to the collection of internal data causes the application program to perform additional instructions not included in the final application program version. These additional instructions would, in fact, be part of the instructions executed during benchmark testing of the program used for this testing.

As a result, current benchmark testing is inherently inaccurate in that the tested program is not the actual program delivered to end users.

There is also a non-insertion method by which developers perform benchmarking. Currently, the non-insertion techniques used by developers who attempt to perform benchmark testing include a variety of methods that estimate when the program reaches the desired target points within the code. These external techniques include visually detecting a display of events that occur on the computers monitor. Often these methods also include attempting to synchronize the operation of the application program with a test control program also running on the computer. The control program performs the timing measurement and tries to externally determine via the visual cues, call backs, or events detectable via the message queue when to stop the timing. This technique has a low level of accuracy due to the control program essentially estimating when to start and/or stop the timings. It is limited to the granularity of measurement achievable via the visual cues as well as the inconsistent time occurring between the control program registering the start timing and the invocation of the user interface or programmatic interface action which begins the functionality to be timed. Additionally, the use of this external test control program also changes the testing environment for the application program in that a second process is concurrently running with the application program being tested. This second program or process is consuming computer resources such as processing time and memory. As a result, any results obtained using this method does not accurately represent the results, which occurred in the final version of the application program run within a typical user's working environment. To avoid the overhead of the control program, the timings are sometimes

performed by use of a stopwatch but this adds an inconsistent and non-negligible overhead both in the starting and the stopping of the timings, and also relies on visual cues making it inherently inaccurate.

Application developers are in need of a mechanism to insert permanent target points to application programs in a manner which does not significantly increase the overhead requirements for the application program while still providing the developers with a mechanism to collect and report the internal operating state data for the application program at precise intervals. In addition, application developers need a mechanism by which this testing process may be easily enabled, disabled, and configured to perform a large variety of different tests.

Summary of the Invention

In accordance with the present invention, the above and other problems are solved by providing a method, apparatus, and article of manufacture for inserting performance markers, also generically referred to as code markers, into programs to obtain and provide benchmark timing data regarding the run-time operation of the programs.

One aspect of the present invention is a computing system having a mass storage device and a system timer for obtaining benchmark timing for a portion of an application program execution. The computing system has an init module for determining if the timestamp data is to be collected during the operation of the application program, a performance marker module for obtaining and storing the timestamp data for later retrieval, an uninit module for formatting and storing the obtained timestamp data into a data file within the mass storage device that permits retrieval after the termination of the application

program, and a performance benchmark data post processing module for determining the benchmark timing from two or more timestamp data entries. The init module is executed before any timestamp data is collected. The performance marker module is executed each time benchmark timestamp data and overhead timestamp data is to be collected. The uninit module is executed after all timestamp data desired has been collected and just before the application exits. The performance benchmark data post processing module determines the benchmark timing from timestamp entries stored within the data file.

Another such aspect is a method for obtaining benchmark timing for a portion of an application program execution. The method includes inserting one or more code markers into the application program at locations within the application program corresponding to the point at which benchmark timing data is desired and determining if benchmark timing data is to be collected at each code marker by checking for the existence of processing modules identified by an identification key within a system registry. If benchmark timing data is to be collected at each code marker, the method generates a benchmark data record containing the collected benchmark timing data each time the code markers are reached, stores the benchmark data records within a data memory block within the processing modules identified by the identification key within the system registry, retrieves the benchmark data records from the data memory block for transfer to a mass storage device once all of the run-time internal state data has been collected, and processes the benchmark data records stored within the mass storage device to determine the benchmark timing defined between two benchmark data records.

Yet another aspect of the present invention is a computer data product readable by a computing system and encoding a computer program of instructions for executing a computer

process for obtaining run-time internal state data within an application program, The computer process comprising the steps of inserting one or more code markers into the application program at locations within the application program corresponding to the point at which benchmark timing data is desired and determining if benchmark timing data is to be collected at each code marker by checking for the existence of processing modules identified by an identification key within a system registry. If benchmark timing data is to be collected at each code marker, the computer process generates a benchmark data record containing the collected benchmark timing data each time the code markers are reached, stores the benchmark data records within a data memory block within the processing modules identified by the identification key within the system registry, retrieves the benchmark data records from the data memory block for transfer to a mass storage device once all of the run-time internal state data has been collected, and processing the benchmark data records stored within the mass storage device to determine the benchmark timing defined between two benchmark data records.

The invention may be implemented as a computer process, a computing system or as an article of manufacture such as a computer program product. The computer program product may be a computer storage medium readable by a computer system and encoding a computer program of instructions for executing a computer process. The computer program product may also be a propagated signal on a carrier readable by a computing system and encoding a computer program of instructions for executing a computer process.

The great utility of the invention is that it provides application program developers with a mechanism for inserting performance markers into programs to obtain and provide data

regarding the run-time operation of the programs. These and various other features as well as advantages, which characterize the present invention, will be apparent from a reading of the following detailed description and a review of the associated drawings.

Brief Description of the Drawings

Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

Fig. 1 illustrates an application program testing system according to one embodiment of the present invention.

Fig. 2 illustrates a general purpose computing system for use in implementing as one or more computing embodiments of the present invention.

Fig. 3 illustrates another application program testing system according to another embodiment of the present invention.

Fig. 4 illustrates a performance benchmark statically linked library and a performance benchmark dynamically linked library for use in program testing according to an example embodiment of the present invention.

Fig. 5A illustrates a sample performance benchmark data record according to an embodiment of the present invention.

Fig. 5B illustrates a sample performance benchmark data file according to an embodiment of the present invention.

Fig. 5C illustrates a timing sequence for code marker benchmark timing according to an embodiment of the present invention.

Fig. 6 illustrates an operational flow for an initialization module within a performance markers module according to an embodiment of the present invention.

Fig. 7 illustrates an operational flow for a markers data module within a performance markers module according to another embodiment of the present invention.

5 Fig. 8 illustrates an operational flow for an uninitialization module within a performance markers module according to another embodiment of the present invention.

Detailed Description of the Invention

This is an application to a method, apparatus, and article of manufacture for inserting performance markers into programs to obtain and provide benchmark timing data regarding
10 the run-time operation of the programs.

Fig. 1 illustrates an application program testing system according to one embodiment of the present invention. Typically, when an application program 101 is being tested, the application program 101 interacts with a test measurement system 102 in order to control the operation of the application program 101 during the test. The test measurement system 102
15 transmits a run command 121 to the application program being tested 101 to instruct the program 101 to begin its operations. A user typically has inserted one or more code markers within the application program 101 to indicate the points during the operation of the application program 101 in which runtime data is desired. When the operation of the application program 101 reaches a code marker, a code marker indication 122 is transmitted
20 to the test measurement system 102.

includes a general-purpose computing device in the form of a conventional personal computer 200, including a processor unit 202, a system memory 204, and a system bus 206 that couples various system components including the system memory 204 to the processor unit 200. The system bus 206 may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus and a local bus using any of a variety of bus architectures. The system memory includes read only memory (ROM) 208 and random access memory (RAM) 210. A basic input/output system 212 (BIOS), which contains basic routines that help transfer information between elements within the personal computer 200, is stored in ROM 208.

The personal computer 200 further includes a hard disk drive 212 for reading from and writing to a hard disk, a magnetic disk drive 214 for reading from or writing to a removable magnetic disk 216, and an optical disk drive 218 for reading from or writing to a removable optical disk 219 such as a CD ROM, DVD, or other optical media. The hard disk drive 212, magnetic disk drive 214, and optical disk drive 218 are connected to the system bus 206 by a hard disk drive interface 220, a magnetic disk drive interface 222, and an optical drive interface 224, respectively. The drives and their associated computer-readable media provide nonvolatile storage of computer readable instructions, data structures, programs, and other data for the personal computer 200.

Although the exemplary environment described herein employs a hard disk, a removable magnetic disk 216, and a removable optical disk 219, other types of computer-readable media capable of storing data can be used in the exemplary system. Examples of these other types of computer-readable mediums that can be used in the exemplary operating

environment include magnetic cassettes, flash memory cards, digital video disks, Bernoulli cartridges, random access memories (RAMs), and read only memories (ROMs).

A number of program modules may be stored on the hard disk, magnetic disk 216, optical disk 219, ROM 208 or RAM 210, including an operating system 226, one or more application programs 228, other program modules 230, and program data 232. A user may enter commands and information into the personal computer 200 through input devices such as a keyboard 234 and mouse 236 or other pointing device. Examples of other input devices may include a microphone, joystick, game pad, satellite dish, and scanner. These and other input devices are often connected to the processing unit 202 through a serial port interface 240 that is coupled to the system bus 206. Nevertheless, these input devices also may be connected by other interfaces, such as a parallel port, game port, or a universal serial bus (USB). A monitor 242 or other type of display device is also connected to the system bus 206 via an interface, such as a video adapter 244. In addition to the monitor 242, personal computers typically include other peripheral output devices (not shown), such as speakers and printers.

The personal computer 200 may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer 246. The remote computer 246 may be another personal computer, a server, a router, a network PC, a peer device or other common network node, and typically includes many or all of the elements described above relative to the personal computer 200. The network connections include a local area network (LAN) 248 and a wide area network (WAN) 250. Such networking environments are commonplace in offices, enterprise-wide computer networks, intranets, and

the Internet.

When used in a LAN networking environment, the personal computer 200 is connected to the local network 248 through a network interface or adapter 252. When used in a WAN networking environment, the personal computer 200 typically includes a modem 254 or other means for establishing communications over the wide area network 250, such as the Internet. The modem 254, which may be internal or external, is connected to the system bus 206 via the serial port interface 240. In a networked environment, program modules depicted relative to the personal computer 200, or portions thereof, may be stored in the remote memory storage device. It will be appreciated that the network connections shown are exemplary, and other means of establishing a communications link between the computers may be used.

Additionally, the embodiments described herein are implemented as logical operations performed by a computer. The logical operations of these various embodiments of the present invention are implemented (1) as a sequence of computer implemented steps or program modules running on a computing system and/or (2) as interconnected machine modules or hardware logic within the computing system. The implementation is a matter of choice dependent on the performance requirements of the computing system implementing the invention. Accordingly, the logical operations making up the embodiments of the invention described herein can be variously referred to as operations, steps, or modules.

Fig. 3 illustrates another application program testing system according to another embodiment of the present invention. An application program 101 being tested consists of an

application main body module 301, one or more application specifically defined statically linked libraries 302-304, one more application specifically defined dynamically linked libraries 312-314, a performance benchmark statically linked library 305, and a performance benchmark dynamically linked library 315. In the past, application programs typically consisted of all the above modules with the exception of the performance benchmark statically linked library 305 and the performance benchmark dynamically linked library 315. An application developer who writes the application program 101 has specified a collection of processing modules, which may not be organized into the various libraries. These modules are combined together to create the application program 101 that the application developer wishes to test.

The application developer tests the operation of the application program 101 by inserting within any of the application specific modules 301-304 and 312-314 one or more code markers. These code markers comprise function calls to modules within the performance benchmark statically linked library 305. The functionality that is to be performed at a particular benchmark code marker is implemented within these function calls. This functionality may be located within either the performance benchmark statically linked library 305 or the performance benchmark dynamically linked library 315.

The runtime data that the application developer wishes to obtain at each of these code markers is stored within the mass storage device 111 and may be examined and further processed within a performance benchmark data post processing module 316. In order to minimize the runtime overhead associated with the implementation of the processing for a given code marker, the data collected at a particular code marker is stored within memory of

the performance benchmark dynamically linked library 315 and ultimately transferred to the mass storage device 111. Processing of the data collected and displaying the data to an application developer performing a test is performed by the performance benchmark data post processing modules 316. By performing the benchmark data analysis processing end data display functions within a data post processing module 316, the amount of processing performed at runtime to implement a code marker is minimized.

Fig. 4 illustrates a performance benchmark statically linked library and a performance benchmark dynamically linked library for use in program testing according to an example embodiment of the present invention. The performance benchmark statically linked library 305 and the performance benchmark dynamically linked library 315 implement the functionality needed to insert code marker data collection within an application program 101. The performance benchmark statically linked library 305 comprises three modules: a linked Init module 401, a linked performance marker module 402, and a linked unInit module 403. The linked Init module 401 is accessed using an Init call 411 that is called once at the beginning of the application program 101 that is being tested. The performance marker module 402 is accessed using a marker call 412 which is called each time a benchmark code marker inserted within the application program 101 is reached. Finally, the Linked unInit module 403403 is accessed using an uninit call 413. The uninit call 413 is called once at the end of the execution of the application program 101 to complete the data collection process.

The processing performed to implement the code markers requires the data collection processing modules that hold the runtime state data be initialized before any of the code markers are reached. This initialization process occurs within the linked init module 401.

Once the data collection processing modules have been initialized, any number of code markers may be called using the marker call 412 to the linked performance marker module 402. Each code marker will cause a corresponding call to the linked performance marker module 402, which in turn captures and stores the benchmark runtime data into the data collection processing modules. In addition, each code marker generates and stores a benchmark data record into a computer systems memory containing the captured data.

When the processing has been completed, a single unInit call 413 is made to the linked unInit module 403 to retrieve all of the benchmark data records from memory for storage onto the mass storage device 111 and/or display to an application developer on his or her terminal 112. The benchmark data records are stored within a file system on the mass storage device 111 in order to allow the records to be accessed and analyzed using a performance benchmark data post processing module 316.

Within each of the three processing modules within the performance benchmark statically linked library 305, the processing simply includes a function call to corresponding dynamically linked libraries (DLL) within the performance benchmark dynamically linked libraries 315. With such an arrangement, a single performance benchmark statically linked library 305 may be statically linked within an application program 101, and may be small in size, while permitting the particular functionality to be performed within a benchmark test to be defined within the dynamically linked libraries. As such, a single mechanism may be used within an application program 101 that easily allows a plurality of different tests to be performed simply by changing the identity of the performance benchmark dynamically linked library 315 that are used as part of a single test.

parameter. The DLL module 422 may store this timing data or decide to collect some other
required runtime state data and to store this runtime state data within a performance marker
data memory block 424. By having the statically linked code marker module make a timing
measurement and then pass that timing measurement into the DLL module 422, there is a
5 minimal amount of time delay occurrence between when the developer has chosen to make
the timing and when it actually occurs. There is thus only a small and negligible overhead
that occurs due to the clock cycles involved in making a function call to the statically linked
code marker module 402. The marker DLL module 422 generates a performance data record
for each corresponding code marker called to the marker DLL 422. These performance data
10 records are simply stored as a concatenated array of records within the memory block 424.

Once all the processing has been completed, the unInit module 404 is called using
unInit call 413. This module 404 also checks to determine if the Init module 401 has
indicated that benchmark processing is to occur. If this benchmark processing is not to
occur, the linked unInit module 404 simply returns to the application program 101. If the
15 benchmark processing is to occur, the linked uninit module 404 calls the corresponding
unInit DLL module 423. The unInit DLL 423 module retrieves all of the benchmark data
records from the memory block 424, formats them appropriately, and stores these records
within the mass storage device 111. Once these records reach the mass storage device 111,
further analysis, review, and subsequent processing may be performed by the application
20 developer as needed.

Because the particular benchmark code marker process that is to occur during a given
test is implemented with in the three DLL modules 421-423, the performance benchmarks,

according to the present invention are readily extensible in that a single yet simple interface to a data collection mechanism may be specified in which the particular nature of the test performed does not need to be embedded in the application program 101. In fact, this processing is contained completely within the set of three DLL modules 421-423.

5 Additionally, the overhead associated with embedding the calls to the performance benchmark modules within an application program may be minimized. This fact is further emphasized by including all of the state difference processing needed to determine how long a block of code requires for execution and to determine which state variables have changed during the execution of a given segment of code, within the post processing operations
10 performed on the set benchmark data records.

Fig. 5A illustrates a sample performance benchmark data record according to an embodiment of the present invention. Each benchmark data record 501 comprises a plurality of data fields used to represent the current state of an application program 101 at the time a code marker is reached. The record 501 includes an application identifier 511 that is used to
15 identify uniquely the application program 101 from which the data record was generated. The record 501 includes a code marker Identifier 512 which is used to identify the particular code marker that generated this data record 501. Finally, the data record 501 includes two timestamp data fields, a Benchmark Timestamp data 513 and an Overhead Timestamp data 514.

20 The Benchmark Timestamp data 513 is obtained immediately after the code marker has been reached. As discussed above in Fig. 4, the code marker will generate a function call to the Linked Performance Marker module 402 within the Performance Marker Link Library

module 305. This time stamp is obtained within the Linked Performance Marker module 402 immediately after it is determined that the performance marker processing is to occur. The timestamp is obtained as soon as possible to attempt to minimize the latency between the application program's arrival at the code marker within its code and the execution of the instructions that actually obtain the timestamp measurement.

Once this time stamp data has been obtained, a call is made to the Marker_DLL module 422 to complete the performance marker processing. Once this processing has been completed, a second timestamp is obtained. This second timestamp, an Overhead Timestamp data 514, represents the best approximation for the time at which the processing returned from the performance marker processing performed within the Linked Performance Marker module 402 and the Marker_DLL module 422. The second timestamp completes the benchmark data record 501 that is stored within the performance marker data memory block 424.

Fig. 5B illustrates a sample data file 502 for a benchmark process that determines the time required to perform various operations within an application program 101. Each data record comprises four fields: an AppID 521, a code marker ID 522, a time stamp for a code marker timestamp 523, and a time stamp for an overhead timestamp 524. The time stamps in this illustrated embodiment may be obtained from a system timer/counter found within many computing systems. This system timer is related to the operating clocks used within a computing system and thus relates directly to the time, measuring clock cycles, required to reach a particular point in the execution of the program. As such, the difference between various time stamps, after subtracting any overhead time, would represent the amount of

time, as measured in clocks cycles, needed to perform the processing between any two code markers. The overhead time estimate is determined by calculating the difference between the Benchmark Timestamp data 513 and the Overhead Timestamp data 514.

Fig. 5C illustrates a timing sequence for code marker benchmark timing according to an embodiment of the present invention. The timing diagram illustrates a sequence of four code markers BP1 531, BP2 534, BP3 537, and BP4 540. Each of these code markers corresponds to a point in time at which the application program 101 reached each of four code markers placed within its code. As discussed above, each of these four code markers also obtains four additional timestamps, OH1 532, OH2 535, OH3 538, and OH4 541 that measure an estimate for the time at which the processing returned from the performance marker libraries 305, 315 to the application program 101.

In Fig. 5C, a benchmark Δt 551 represents the time required for the application program 101 to complete the processing that occurs between BP1 531 and BP4 540. Because the processing time for this task also includes processing associated with obtaining and storage of the various code markers, the estimate for the overhead processing, in this example Δt_1 533, Δt_2 536, and Δt_3 538, must be subtracted from the difference between BP1 531 and BP4 540. Each of the overhead processing estimates is determined from the difference between the benchmark time stamp and the overhead timestamp. For example,

$$\Delta t_2 \text{ 536} = \text{OH2 535} - \text{BP2 534.} \quad (1)$$

The same determination may be made for each of the other time stamps obtained during a test. In addition, the timestamp is measured in units of clock cycle counts in the preferred

embodiment. As such, all time measurements discussed herein need to be scaled by the time for a single clock cycle if measurements in seconds is desired.

Given the above explanation, the measurement of an accurate benchmark is obtained by calculating the difference between two time stamps, BP4 540 and BP1 531, for example.

5 The accurate benchmark is calculated by subtracting an estimate of all of the time spent within performance marker libraries 305, 314, from the above difference. In the example in Fig. 5C, the accurate benchmark is:

$$\text{Benchmark} = (\text{BP4 540} - \text{BP1 531}) - (\Delta t1\ 533 + \Delta t2\ 536 + \Delta t3\ 539). \quad (2)$$

10 All of this processing to determine the benchmark timing is performed as part of the Performance Benchmark Data Post Processing module 316 that is run after the application program 101 has completed its operations.

Fig. 6 illustrates an operational flow for an initialization module within a performance markers module according to an embodiment of the present invention. The processing within the initialization process 601 proceeds to an Init module 611. Within the Init module 611,
15 the main application module calls the performance marker init module 401 in order to initialize the data memory block 424 used to hold a collection of benchmark data records. Once complete, the processing proceeds to the Reg Key Check module 612. This module 612 checks a DLL registry key within a system registry on the computer. This registry key provides the identity to a dynamically linked library containing the processing modules
20 needed to implement the code marker processing.

Test module 613 determines whether this registry key exists. If not, processing branches to a Marker Flag False module 618. If a registry key does exist, as determined by

test module 613, processing proceeds to DLL check module 614. This module 614 checks for the presence of the DLL modules within the system as identified in by the previously checked registry key. This module 615 determines the outcome of the previous check for the existence of the DLL module. If the DLL module does not exist, processing again branches
5 to Marker Flag False module 618.

If the DLL module identified by the registry key exists, processing branches to Data Memory Configuration module 616. This configuration module 616 initializes and configures a performance marker data memory block 424 within the DLL. This memory block is used to hold the collection of the benchmark data records generated by the performance
10 benchmarking process. Once complete, a Flag Marker True module 617 sets a marker flag to be true. This flag is used by other processing the to indicate whether not a performance benchmark processing is to occur. Once this processing has completed, the processing ends
602.

Returning to either test operation 612, or 615, if either of these tests are determined to
15 be false, the processing proceeded to Marker Flag False module 618. This flag module 618 sets the marker flag to be false, thus indicating to the processing that performance benchmark processing is not to occur because either the DLL does not exist or the registry key that identifies the DLL to be used does not exist. Once this flag is been set, the processing also ends 602.

20 Fig. 7 is an operational flow for a markers data module within a performance markers module according to another embodiment of the present invention. Within the code marker

processing, the processing starts 701 and test module 711 immediately determines whether benchmark processing is to occur. In one embodiment, this test checks the marker flag that narrow has been previously set within the initialization process. If the code marker processing is not to occur, the processing merely branches to the end 702. As such a

5 benchmark code marker processing simply results in a call to a statically linked library routine which checks a flag and immediately returns back to the main processing modules. As such, the overhead associated with the execution of an application program containing performance marker is quite minimal. This approach allows application programs to contain performance markers used to test and evaluate the performance of the application program in

10 the program itself as they would ship to end users. This testing that occurs need not be performed on a modified version of the application program which does not represent the state of the product which is actually ship to end users. This operation overhead processing does not impinge upon the performance of the application program itself, while still providing an extensible means by which the testing of the application program may be

15 performed.

If the flag indicates that performance code markers are to be processed, processing proceeds to the Obtain Breakpoint Timestamp module 712. This module 712, which is located within the link library, obtains the first of two timestamp data measurements. This timestamp data measurement corresponds to the Benchmark Timestamp data 513 within the

20 benchmark data record 501. Next call marker DLL module 713 calls the DLL module to gather any additional data relating to the state of the application program at the time the code

marker is reached. This module 713 passes the Benchmark Timestamp data 513 value to the Marker_DLL 422 for use in generating the benchmark data record 501.

Store Marker Data Module 714 generates the benchmark data record 501 using the Benchmark Timestamp data 513 value passed from the call marker DLL module 713. This
5 Store Marker Data module 714 then stores the generate benchmark data record 501 within the performance marker data memory block 424. As part of this process, a benchmark data record is generated within a format desired for the particular data being collected. Once the data has been stored, an Overhead Timestamp module 715 may obtain a second timestamp measurement and store the obtained value within the Overhead Timestamp Data field 514 of
10 the benchmark data record 501. As discussed above, the timing data typically includes a time stamp associated with the beginning of the benchmark code marker processing.

Because the above collection of modules that are needed to obtain the data, format the data, and store the data within the memory block 424 takes some measurable amount of processing time, as measured in clock cycles, to perform its operations, a more accurate
15 estimate for a benchmark for the processing that occurs between two code markers would attempt to subtract the time spent within all of these benchmark modules. As such, this record may include a second time stamp associated with time at which the processing returns back to the main application. The second time stamp may be generated and stored within the memory block by the Overhead Timestamp module 715. With all of the data now collected
20 and stored within the memory block 424, the processing ends 702.

Fig. 8 is an operational flow for an uninitialization module within a performance markers module according to another embodiment of the present invention. Within the unInit processing, the processing starts 801, and tests module 811 immediately determines whether benchmark processing is to occur. In one embodiment, this test module 811 checks the marker flag that had been previously set within the initialization process. If the code marker processing is not to occur, the processing merely branches to the end 802. As such, the unInit processing simply results in a call to the linked library routine which checks a flag and immediately returns back to main processing. As discussed above, this sequence of operations imposes a minimal amount of processing upon an application program 101 when sent to the end user without the performance marker DLLs.

If performance marker processing is to occur, this set of modules formats and stores the collected set of benchmark data records for later use. The processing proceeds from test operation 811 to a Call unInit DLL module 812. This module 812, which is located within the statically link library, calls the DLL module to move the collection of benchmark data records from the DLL memory block 424 to mass storage 111. Typically, these records are stored within a file in the computer's file system for later use. This data may be stored in either a binary format, or may be converted into a human readable form. Because the uninit process occurs at the end of the testing process, occurs only once, and occurs after all time critical events are over, this data conversion processing may occur within the DLL modules without affecting the results from the testing. Alternatively, this data formatting operation may occur within the post processing modules 316 at a later date. Once the data has been

stored for later use, a Free Memory Block module 814 performs any system housekeeping processing necessary to free the memory used by the DLL modules that is no longer needed.

Thus, the present invention is presently embodied as a method, apparatus, computer storage medium, or propagated signal containing a computer program for manufacture for
5 inserting performance markers into programs to obtain and provide data regarding the run-time operation of the programs.

While the above embodiments of the present invention describe insertion of performance markers into programs to obtain and provide data regarding the run-time operation of the programs, one skilled in the art will recognize that the type of run-time data
10 collected and returned to a user may represent any data collectable from the computing system and its operating state. As long as the performance markers are inserted within the application program at the locations in which the testing is to occur, and as long as the particular data collection processing is specified within the libraries, the present invention would be useable in any testing environment. It is to be understood that other embodiments
15 may be utilized and operational changes may be made without departing from the scope of the present invention.

As such, the foregoing description of the exemplary embodiments of the invention has been presented for the purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications
20 and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not with this detailed description, but rather by the claims appended

hereto. Thus the present invention is presently embodied as a method, apparatus, computer storage medium, or propagated signal containing a computer program for providing a method, apparatus, and article of manufacture for inserting performance markers into programs to obtain and provide data regarding the run-time operation of the programs.

Claims

WHAT IS CLAIMED IS:

- 1 1. A computing system having a mass storage device and a system timer for
- 2 obtaining benchmark timing for a portion of an application program execution, the computing
- 3 system comprising:
- 4 a mass storage system;
- 5 an init module for determining if the timestamp data is to be collected during the
- 6 operation of the application program;
- 7 a performance marker module for obtaining and storing the timestamp data for later
- 8 retrieval;
- 9 an uninit module for formatting and storing the obtained timestamp data into a data file
- 10 within the mass storage device that permits retrieval after the termination of the application
- 11 program; and
- 12 a performance benchmark data post processing module for determining the benchmark
- 13 timing from two or more timestamp data entries;
- 14 wherein
- 15 the init module is executed before any timestamp data is collected;
- 16 the performance marker module is executed each time benchmark timestamp data
- 17 and overhead timestamp data is to be collected;
- 18 the uninit module is executed after all timestamp data desired has been collected;
- 19 and
- 20 the performance benchmark data post processing module determines the
- 21 benchmark timing from timestamp entries stored within the data file.

1 2. The computing system according to claim 1, wherein the init module determines if
2 timestamp data is to be collected.

1 3. The computing system according to claim 2, wherein init module makes the
2 determination that timestamp data is to be collected by checking for the existence of an
3 identification key within a system registry;
4 the identification key uniquely identifying the processing modules to be used to collect,
5 format, and store the run-time internal state data to be collected.

1 4. The computing system according to claim 3, wherein the timestamp data
2 comprises a timer count value obtained from the system timer.

1 5. The computing system according to claim 2, wherein the performance marker
2 module collects timestamp data only if the init module has determined that the timestamp data is
3 to be collected.

1 6. The computing system according to claim 5, wherein the performance marker
2 module generates a benchmark data record containing a benchmark timestamp data value each
3 time the performance marker module is executed.

1 7. The computing system according to claim 6, wherein the benchmark data record
2 further containing an overhead timestamp data value each time the performance marker module is
3 executed.

1 8. The computing system according to claim 7, wherein the performance marker
2 module stores the benchmark data records within a data memory block within the processing
3 modules identified by an identification key within a system registry.

1 9. The computing system according to claim 8, wherein the uninit module retrieves
2 the benchmark data records from the data memory block for transfer to the data file on the mass
3 storage device.

1 10. The computing system according to claim 9, wherein the performance benchmark
2 data post processing module determines the benchmark timing from difference between two
3 benchmark timestamp data entries stored within the data file.

1 11. The computing system according to claim 10, wherein the performance
2 benchmark data post processing module determines the benchmark timing by subtracting an
3 estimate for the total overhead processing from the difference between two benchmark timestamp
4 data entries stored within the data file.

1 12. The computing system according to claim 11, wherein the estimate for the total
2 overhead processing is determined by totaling the difference between the overhead timestamp
3 value and the benchmark timestamp value for all code markers between the two benchmark
4 timestamp entries used to determine the benchmark timing.

1 13. A method for obtaining benchmark timing for a portion of an application program
2 execution, the method comprising:

3 inserting one or more code markers into the application program at locations within the
4 application program corresponding to the point at which benchmark timing data is desired;

5 determining if benchmark timing data is to be collected at each code marker by checking
6 for the existence of processing modules identified by an identification key within a system
7 registry;

8 if benchmark timing data is to be collected at each code marker:

9 generating a benchmark data record containing the collected benchmark timing
10 data each time the code markers are reached;
11 storing the benchmark data records within a data memory block within the
12 processing modules identified by the identification key within the system registry;
13 retrieving the benchmark data records from the data memory block for transfer to
14 a mass storage device once all of the run-time internal state data has been collected; and
15 processing the benchmark data records stored within the mass storage device to
16 determine the benchmark timing defined between two benchmark data records.

1 14. The method according to claim 13, wherein the benchmark timing from difference
2 between two benchmark timestamp data entries stored within the data file.

1 15. The method according to claim 14, wherein the benchmark timing is determined
2 by subtracting an estimate for the total overhead processing from the difference between two
3 benchmark timestamp data entries stored within the data file.

1 16. The method according to claim 15, wherein the estimate for the total overhead
2 processing is determined by totaling the difference between an overhead timestamp value and a
3 benchmark timestamp value for all code markers between the two benchmark timestamp entries
4 used to determine the benchmark timing.

1 17. The method according to claim 16, wherein
2 the benchmark timestamp value is obtained from a system timer immediately after a code
3 marker is reached;
4 the overhead timestamp value is obtained from the system timer immediately before
5 processing returns to the application program from performance marker processing.

1 18. A computer data product readable by a computing system and encoding a
2 computer program of instructions for executing a computer process for obtaining run-time
3 internal state data within an application program, said computer process comprising the steps of:
4 inserting one or more code markers into the application program at locations within the
5 application program corresponding to the point at which benchmark timing data is desired;
6 Determining if benchmark timing data is to be collected at each code marker by checking
7 for the existence of processing modules identified by an identification key within a system
8 registry;
9 if benchmark timing data is to be collected at each code marker:
10 generating a benchmark data record containing the collected benchmark timing
11 data each time the code markers are reached;
12 storing the benchmark data records within a data memory block within the
13 processing modules identified by the identification key within the system registry;
14 retrieving the benchmark data records from the data memory block for transfer to
15 a mass storage device once all of the run-time internal state data has been collected; and
16 processing the benchmark data records stored within the mass storage device to
17 determine the benchmark timing defined between two benchmark data records.

1 19. The computer data product according to claim 18, wherein the determining step
2 makes the determination that benchmark timing data is to be collected by checking for the
3 existence of an identification key within a system registry;
4 the identification key uniquely identifies the processing modules to be used to collect,
5 format, and store the run-time internal state data to be collected.

1 20. The computer data product according to claim 19, wherein the determining step
2 further makes the determination that benchmark timing data is to be collected by checking for the
3 existence of processing modules identified by the identification key within the system registry.

1 21. The computer data product according to claim 19, wherein the data memory block
2 is within processing modules identified by the identification key within the system registry.

1 22. The computer data product according to claim 21, wherein the benchmark timing
2 from difference between two benchmark timestamp data entries stored within the data file.

1 23. The computer data product according to claim 22, wherein the benchmark timing
2 is determined by subtracting an estimate for the total overhead processing from the difference
3 between two benchmark timestamp data entries stored within the data file.

1 24. The computer data product according to claim 23, wherein the estimate for the
2 total overhead processing is determined by totaling the difference between an overhead
3 timestamp value and a benchmark timestamp value for all code markers between the two
4 benchmark timestamp entries used to determine the benchmark timing.

1 25. The computer data product according to claim 24, wherein
2 the benchmark timestamp value is obtained from a system timer immediately after a code
3 marker is reached; and
4 the overhead timestamp value is obtained from the system timer immediately before
5 processing returns to the application program from performance marker processing.

1 26. The computer data product according to claim 19, wherein the computer data
2 product comprises a computer readable storage medium readable by a computer upon which
3 encoded instructions used to implement the computer process are stored.

Abstract of the Invention

A method, apparatus, and article of manufacture provide a mechanism for inserting performance markers into programs to obtain and provide data regarding the run-time benchmark timing of the programs. The computing system has an init module for determining if the benchmark timing data is to be collected during the operation of the application program, a performance marker module for obtaining and storing the benchmark timing data for later retrieval, and an uninit module for formatting and storing the obtained benchmark timing data into memory that permits retrieval after the termination of the application program. The init module is executed before any benchmark timing data is collected. The performance marker module is executed each time benchmark timing data is to be collected. The uninit module is executed after all benchmark timing data desired has been collected. The method and computer data product relate to a computer implemented process that inserts one or more code markers into the application program at locations within the application program corresponding to the point at which benchmark timing data is desired and that determines if benchmark timing data is to be collected at each code marker by checking for the existence of processing modules identified by an identification key within a system registry.

Fig. 1

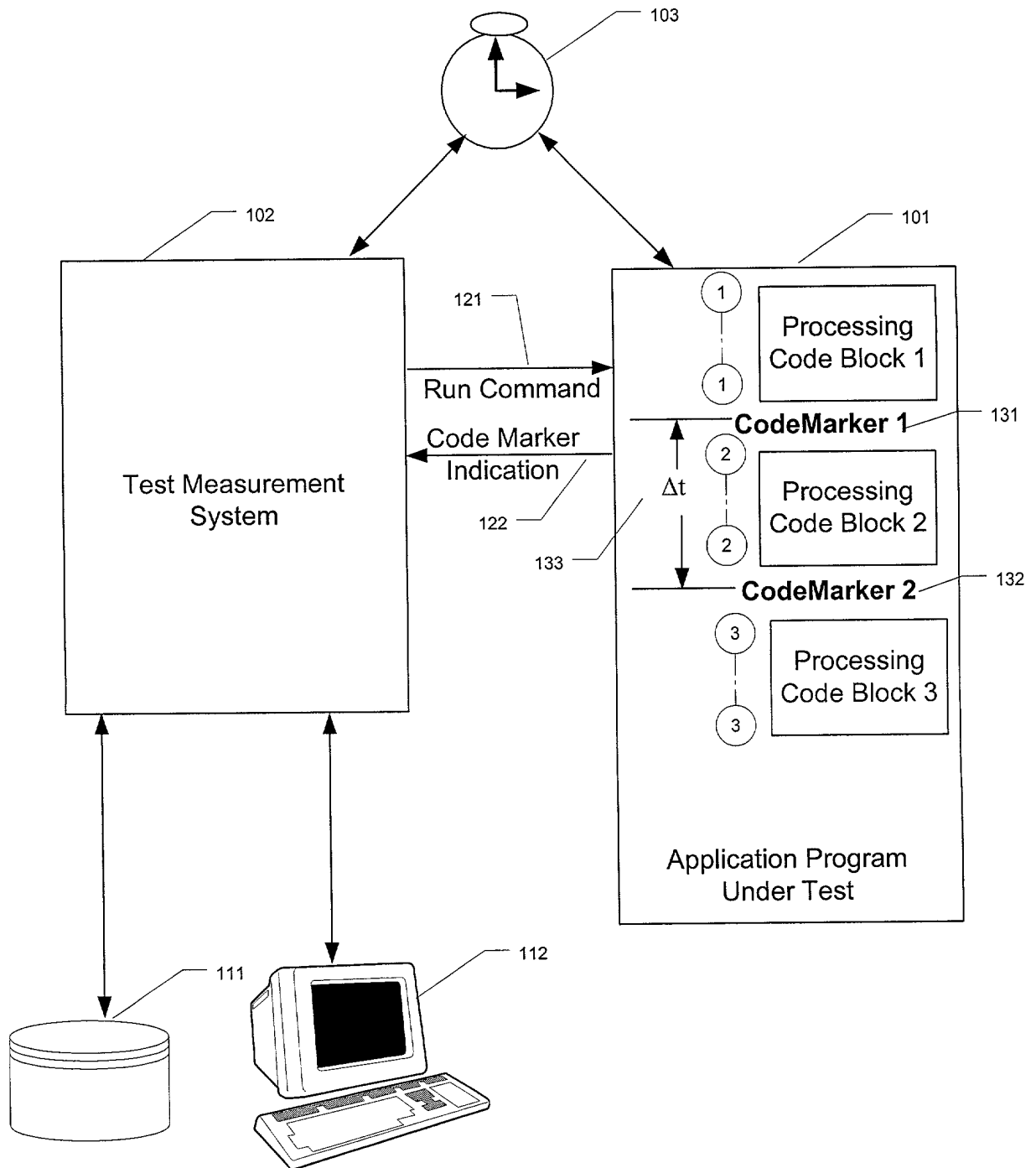


FIG. 2

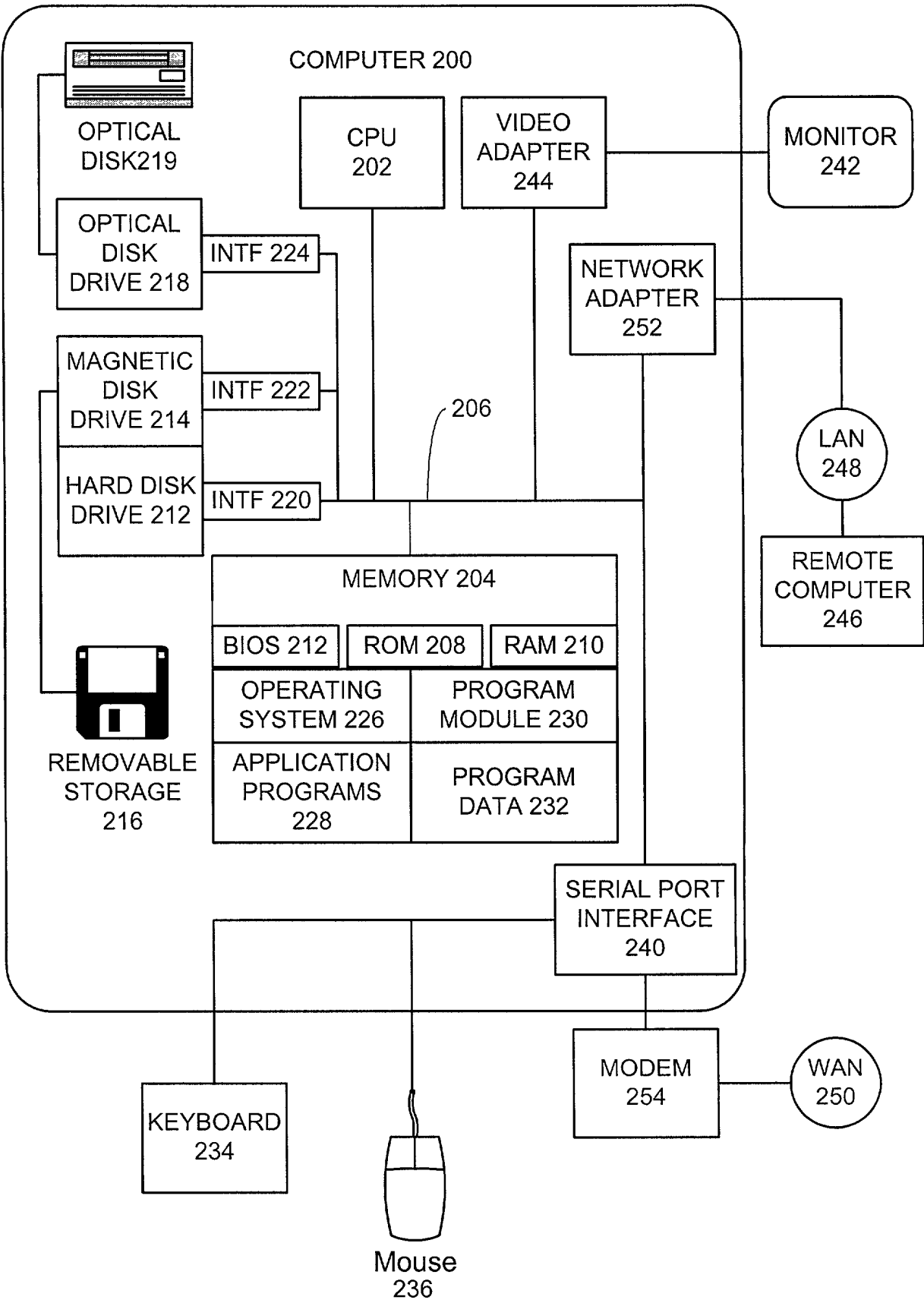


Fig. 3

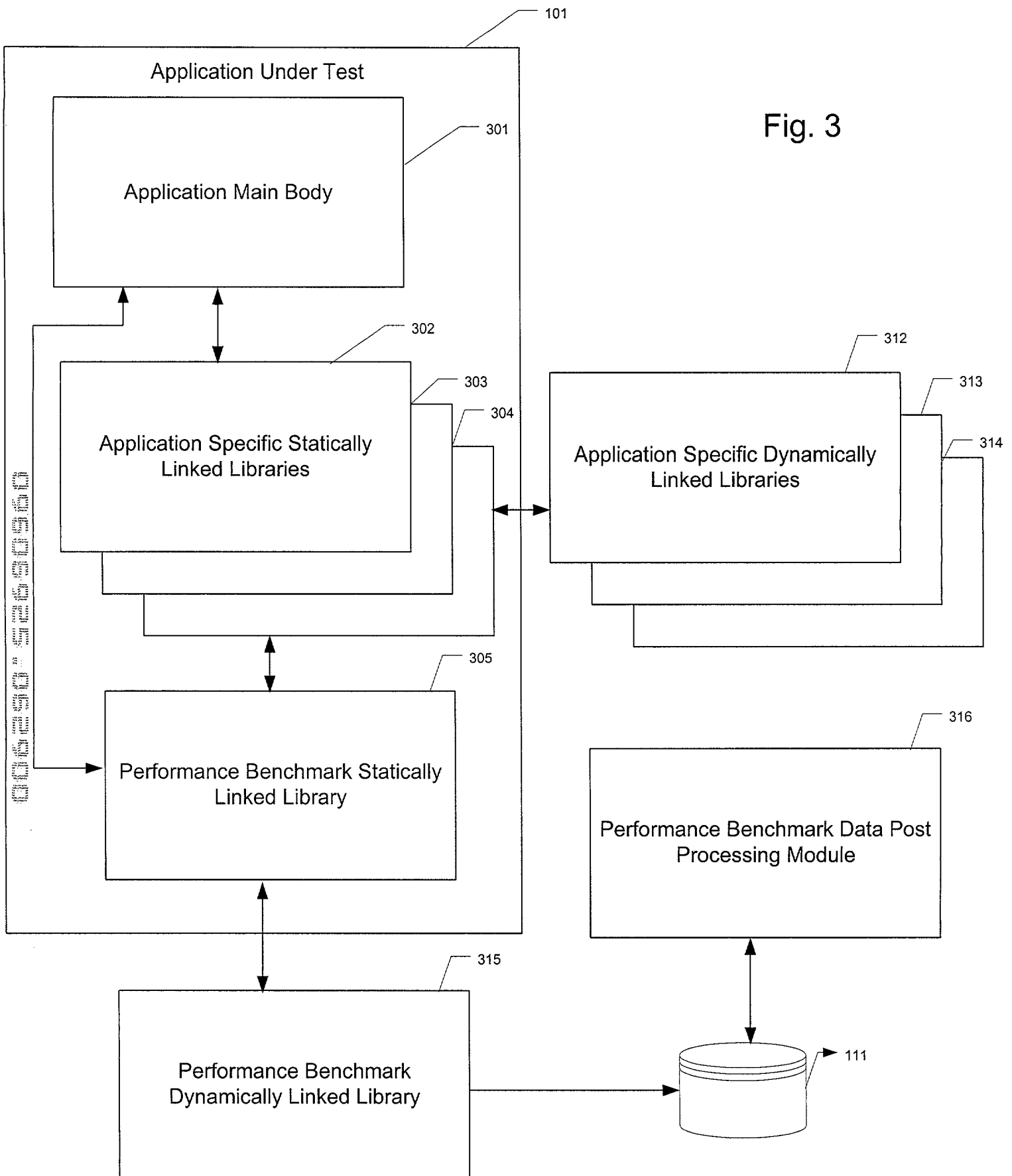


Fig. 4

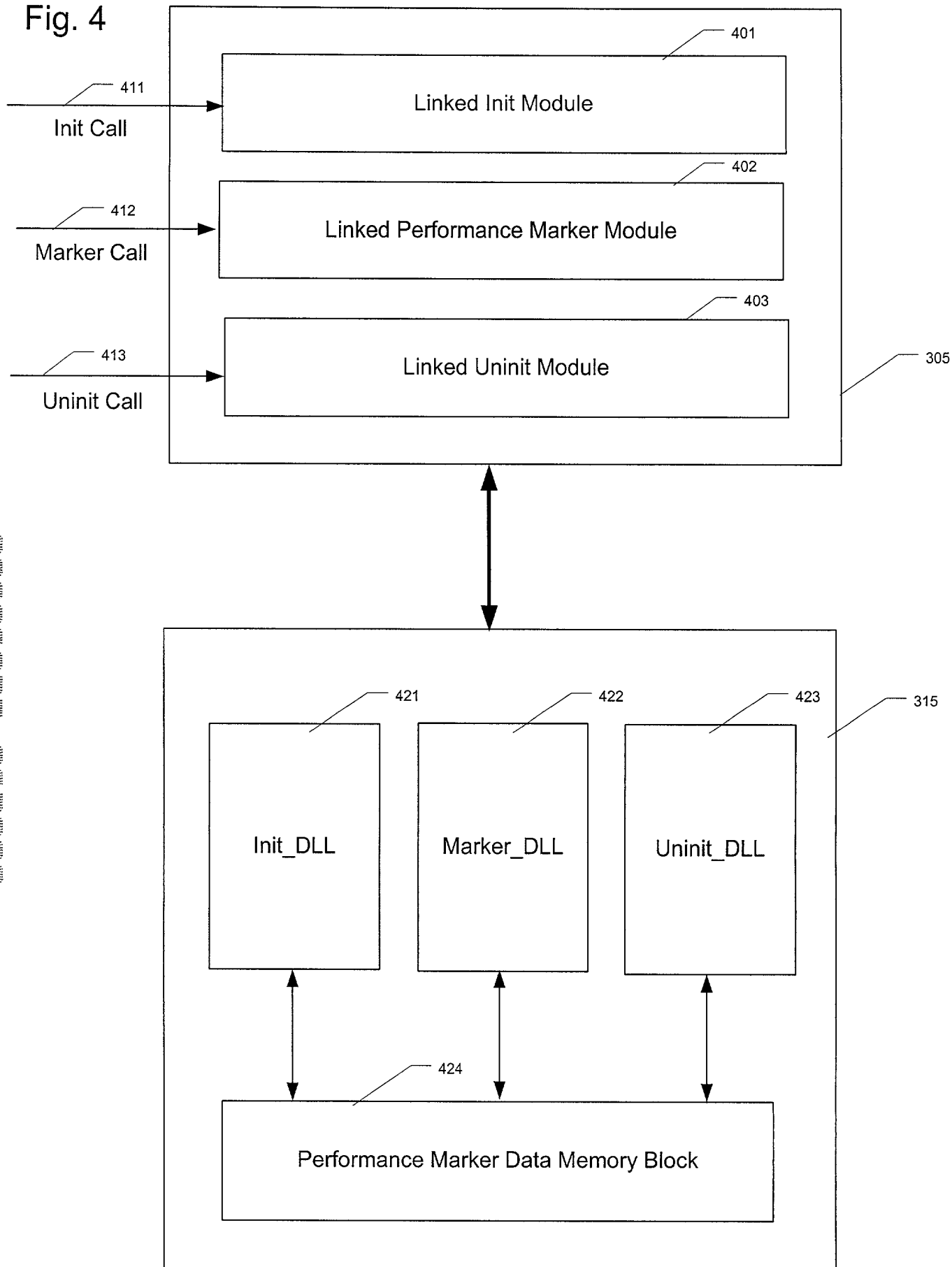


Fig. 5A

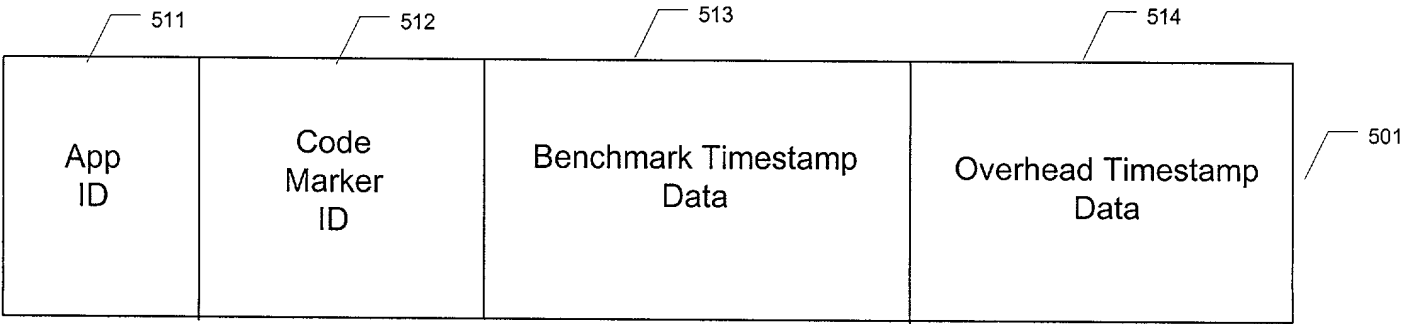
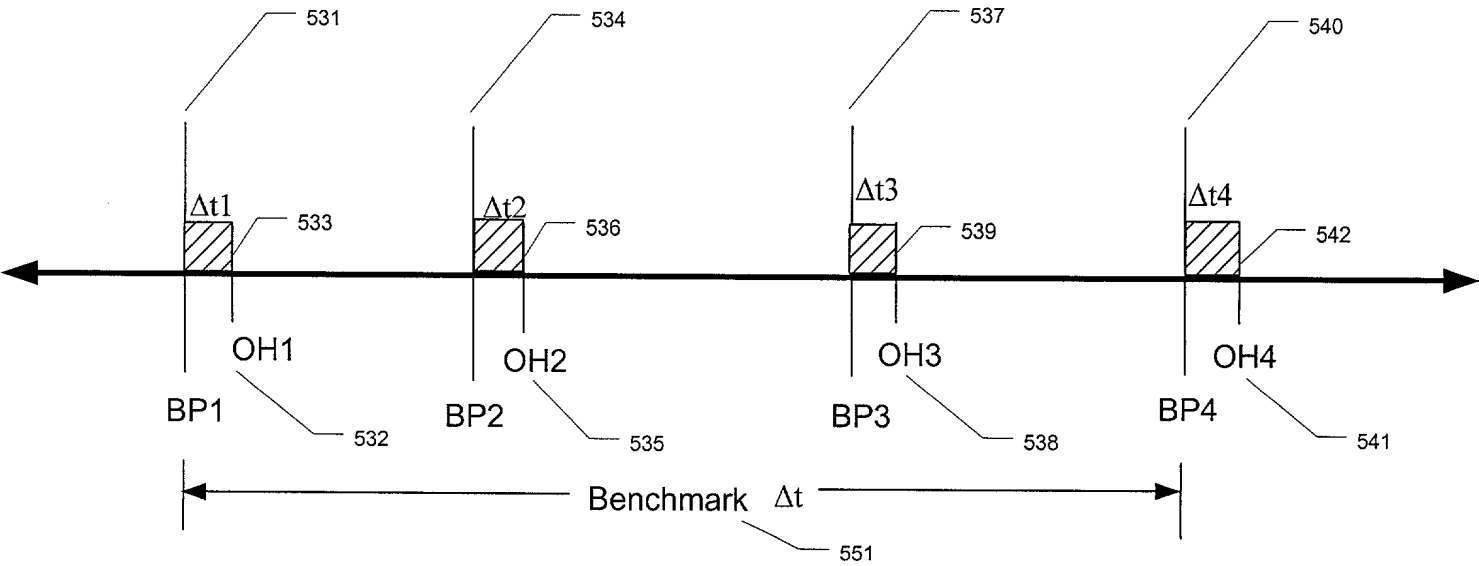


Fig. 5B

Code Marker ID					
521	522	523	524		
1	8	206994621185796	206994621186415		
1	9	206994621186607	206994621186816		
1	4	206994614902758	206994621187365		
1	5	206994621186972	206994621187586		
1	501	206994692692884	206994692694188		
1	6	206995418775616	206995418776757		
1	3	0000000000000300	206995418832491		
1	7	206995419948783	206995419948783		
50	500	206994607250814	206994607250814		
0	2	206995433571294	0000000000000000		

Fig. 5C



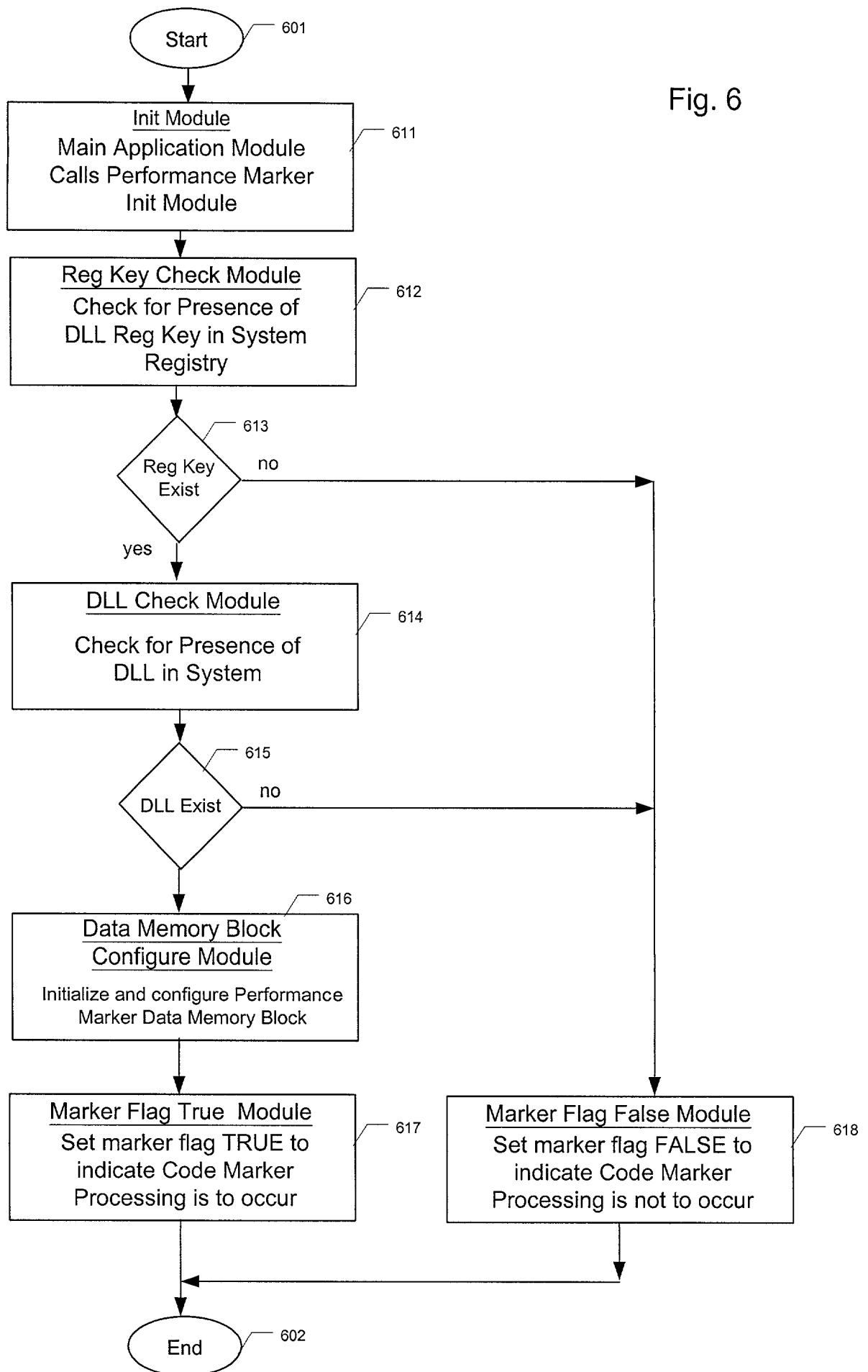


Fig. 7

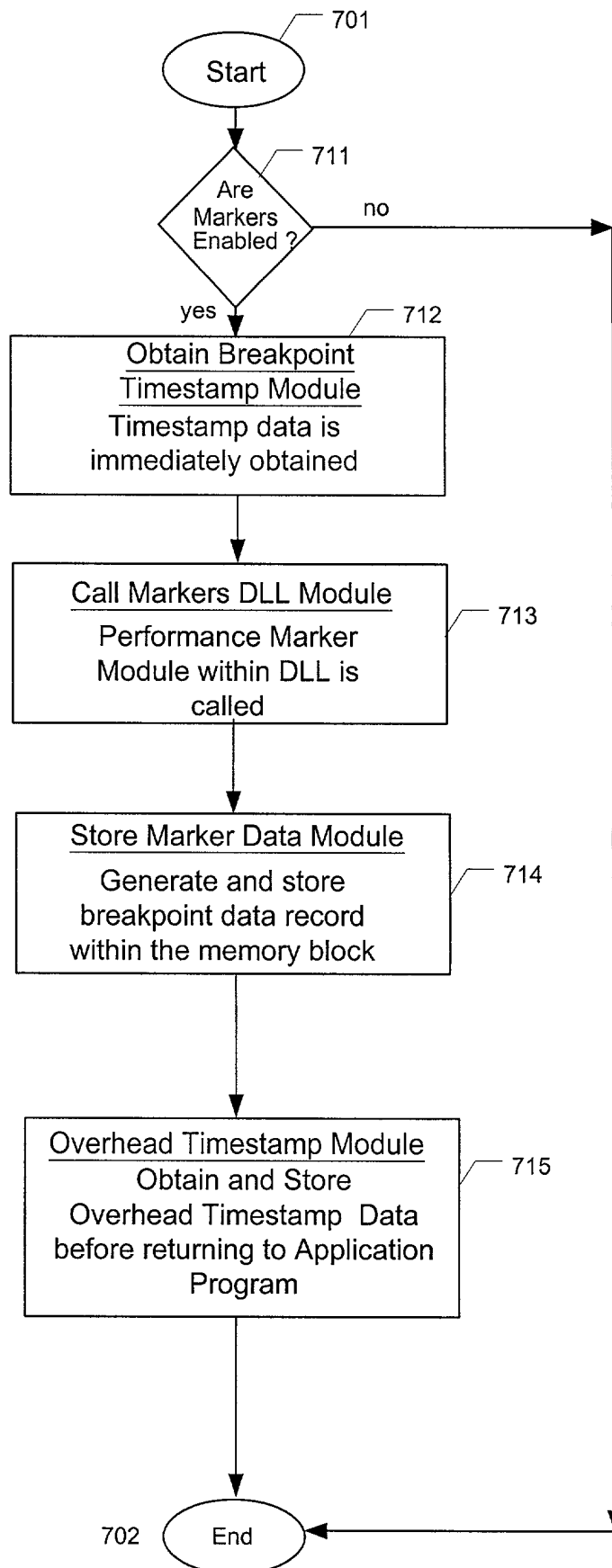
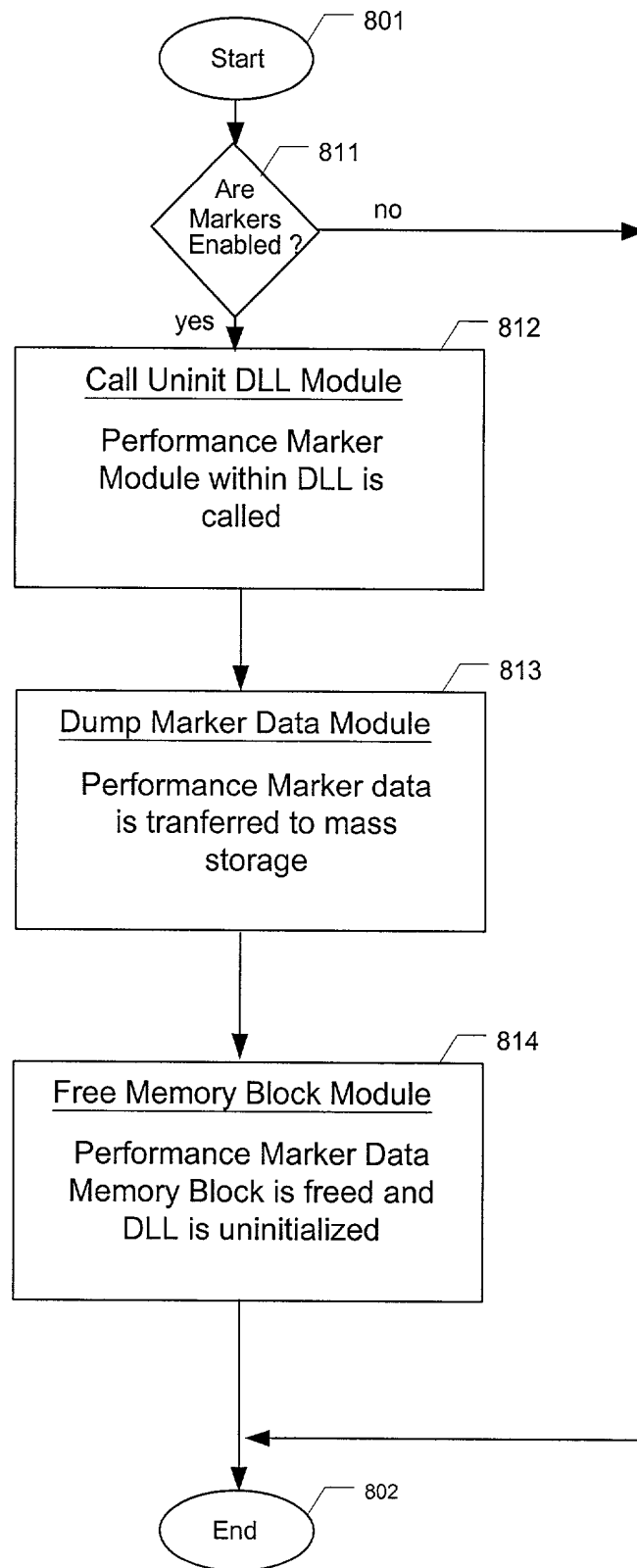


Fig. 8



MERCHANT & GOULD P.C.

United States Patent Application

COMBINED DE CLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: PERFORMANCE MARKERS TO MEASURE BENCHMARK TIMING OF FEATURES IN A PROGRAM, the specification of which is attached hereto, which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

- ☒ no such applications have been filed.
☐ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)
ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (Day, Month, Year)

I hereby appoint the following attorney(s) and/or patent agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

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Carlson, Alan G.	Reg. No. 25,959	Phillips, John B.	Reg. No. 37,206
Caspers, Philip P.	Reg. No. 33,227	Plunkett, Theodore	Reg. No. 37,209
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DiPietro, Mark J.	Reg. No. 28,707	Schumann, Michael D.	Reg. No. 30,422
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Kettelberger, Denise	Reg. No. 33,924	Wu, Tong	Reg. No. 43,361
Keys, Jeramie J.	Reg. No. 42,724	Xu, Min S.	Reg. No. 39,536
Knearl, Homer L.	Reg. No. 21,197	Zeuli, Anthony R.	Reg. No. P45,255
Kowalchyk, Alan W.	Reg. No. 31,535		
Kowalchyk, Katherine M.	Reg. No. 36,848		

In addition, I also hereby appoint the following attorneys to prosecute this application and to transact all business in the U.S. Patent and Trademark Office in connection therewith:

Kate E. Sako, Reg. No. 32,628
Daniel D. Crouse, Reg. No. 32,022

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Merchant & Gould P.C. to the contrary.

Please direct all correspondence in this case to Merchant & Gould P.C. at the address indicated below:

Homer L. Knearl
Merchant & Gould P.C.
P.O. Box 2903
Minneapolis, MN 55402-0903
303.357.1633

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

- (1) prior art cited in search reports of a foreign patent office in a counterpart application, and
- (2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

- (1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim;
- or
- (2) It refutes, or is inconsistent with, a position the applicant takes in:

- (i) Opposing an argument of unpatentability relied on by the Office, or
- (ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.